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Relative Cost of Gas and Electricity for Laboratory Heating Devices

RELATIVE COST OF GAS AND ELECTRICITY FOR LABORATORY HEATING DEVICES

BY

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ENTITLED Relative Cost of Gas and Electricity for Laboratory Heating Service

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

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RELATIVE COST OF GAS AND ELECTRICITY FOR LABORATORY HEATING DEVICES

INTRODUCTION

The great expense of heating appliances and of their use justifies any investigation tending to improve them. The first step is to decide upon the most economical type. In this consideration, the heaters in use in the laboratory may be classified as gas or electric. The gas heaters may then be subdivided into direct flame heaters and hot plates, and the electric devices as self-contained heaters and hot plates. The term "hot plates" is familiar to everyone who has used laboratory apparatus. By a"direct flame" heater is meant one of the Bunsen burner type, which has no permanent conducting medium between the flame and the vessel being heated. "Self-contained" devices are those in which the container is entirely surrounded by the heating coils.

In addition to considering which type is the most economical when used most carefully, it is necessary to consider which type will be used most economically by the average student. Thus, in case a student uses gas, he turns on a Bunsen burner to heat a test tube; and, if he expects to use the burner again during the time he is in the laboratory, he will allow it to burn rather than to turn it off and re-light it when he again needs it. In using an electric heater he is more apt to save the power, for it is much more simple and quicker to throw a switch than to re-light a gas burner.

The relative economy of gas and electricity has been a subject for debate ever since the electric light came into use. So it has been with the heating devices using these two sources of energy. The men who carried on the investigations in these directions were, however, almost invariably employed

by either a gas or an electric company, or companies manufacturing one or the other type of appliance.

R.C. Powell[1] states that economy depends upon (1) the efficiency of the consumer's appliance, (2) cost per cubic foot of gas, or per kilowatt hour for electricity delivered at the meter. In his article he gives extracts from a report by Mr. Harold Gray before the Institute of Electrical Engineers (England) in 1911. Gray evaporated one pound of water at various rates in his experiments. Powell, using Gray's figures, finds that the efficiency varies greatly with the speed of heating. Thus, using an undescribed gas apparatus, he finds an efficiency of 32.5 per cent when burning three cubic feet per hour, while at ten cubic feet per hour , he finds an efficiency of 38.8 per cent. Powell assumes the gas to have a heating value of 600 B.t.u. per cubic foot in all of his calculations. In his calculations of the efficiency of electrical devices, he obtained one of 91 per cent for "self-contained one pint sauce pan", 62.5 per cent for a hot plate and an aluminum utensil, and 62.4 per cent for a hot plate and an earthen ware pot. The rates used for discussion in England are 60 cents per 1000 cubic feet of gas and 2 cents per kilowatt hour for electricity. Using three types of hot plates, Powell found their efficiency to vary from 22 to 45 per cent. Gas efficiency was 35 per cent when heating in a 1½ gallon aluminum utensil; and when the same utensil was heated on the latest type of electric range, an efficiency of 62 per cent was obtained. Judging from Gray's experiments and from his own, Powell concludes that the all around efficiency of gas is at least 25 per cent and that of electricity not over 75 per cent.

When converted into heat, one kilowatt hour gives 3,412 B.t.u.'s. Assuming electricity to be used at 75 per cent efficiency, and gas at 25 per cent 60 kilowatts give the same useful heat as 1000 cubic feet of gas of 600 B.t.u.'s. From this

Powell derives the following table:

Gas at		Electricity at
$0.75	per M equals	1.25 cents per kilowatt hour
0.90		1.50
1.00		1.67
1.25		2.08
1.50		2.50
1.75		2.92
2.00		3.33
2.25		3.75
2.50		4.17

This table shows that some communities and plants can use electricity for heat more economically than gas. This is true, for instance, at some irrigation projects where the power plants operate both summer and winter, the production being cheap in winter because no other use can then be made of the water. Another case is in large plants or universities, where the excess steam from the high pressure heating systems can be utilized to run dynamos.

EXPERIMENTAL

The results of the work done by Gray and Powell give almost conclusive evidence that the University of Illinois can more economically heat laboratory apparatus with electricity than it can heat this apparatus with gas bought of the City of Champaign. This work was undertaken to test out the soundness of this belief.

Data was first obtained on the operating cost of the various types of heaters in use about the chemistry laboratory. All of the heaters were tested under conditions as nearly alike as possible. Finally, results seeming to warrant the attempt, several electric heating devices were constructed.

Testing of the Devices Available. Under the following list of apparatus is given a brief description of the appliance and the method by which each was tested.

(1) A Bunsen burner, three-eighth inch pipe and six inches high, was tested with various sizes of flames. A 600 cubic centimeter beaker containing 250 cubic centimeters of water was heated upon an asbestos mat in such manner that the hottest part of the flame was utilized. Then, in order to determine approximately how efficiently the students of elementary chemistry use the burners, those in one of the first year chemistry classes were observed for several two-hour periods. The average number of students under observation was thirty-two and the average number of flames was twenty-one. The flames were actually in use only about one-fifth of the time that they were burning. The figures for cost, etc., per 1000 large calories utilized in the freshman laboratory are based upon this observation and the assumption that the burners were used to the best advantage during this time.

(2) A Clark Jewel Gas Hot Plate was next tested; it was fourteen by eighteen inches and of type No. 502. Twelve 600 cubic centimeter beakers, as

many as could conveniently be placed upon the plate, containing 250 cubic centimeters of water each, were heated. Several sizes of flames were tried.

(3) Hoskins Electric Heating Appliance, Type MAlll, Series 1008, 110 volts, 5 amperes; top plate, fourteen by fifteen inches. Nine 600 cubic centimeter beakers, each containing 250 cubic centimeters of water, were heated.

(4) Simplex Electric Heating Appliance, T1732, V. 110, A. 4, diameter of plate six inches. This had a four adjustment switch: off, low, medium, and high. Four 100 cubic centimeter beakers, each containing 75 cubic centimeters of water, were heated.

(5) Schaar and Company Kjeldahl Heater, six units. Two of the units were tested by heating two one liter flasks, containing 500 cubic centimeters of water each, at low and at high speed. Cost calculated per unit.

Bunsen Burners in Freshman Laboratory

Average Figures for One Flame

Size Inches	Gas Used per Hr. Cubic Feet	Cost per Hr. Cents	Cost per M Cal. Cents
9	8.2	.82	28
7	5.4	.54	21.5
7	5.5	.55	22
8.5	7.5	.75	26.5
7	5.3	.53	21

Data of Heati

Device Number	Max. Temp. of Plate Deg. Cent.	Time of Heat. to Max. Temp. Min.	Cu. Ft. of Gas, or Kw. Hr.	Cost of Heat. to Max. Cents	Temp. of Water Deg. Cent.	
					Initial	Rise
1	(Six inch flame)				25	73
Bunsen	(Seven inch flame)				24	74
Burner	(Ten inch flame)				26	72
2	276	35	14.8	1.48	22	59
Gas	193	55	14.8	1.48	24	58
Hot Plate	273	35	14.0	1.40	24	70
3	187	51	.401	.401	22	41
Hoskins Electric	218	39	.332	.332	24	56
Hot Plate	272	95	.798	.798	23	49
4 (Low)	181	33	.073	.073	22	53
Simplex Elect. (Med.)	365	30	.134	.134	24	71
Hot Plate (High)	454	50	.331	.331	31	69
5 (Low)	Schaar & Co.	90	.469	.469	23	73
	Kjeldahl	90	.467	.467	24	71
(High)	Heater	60	.992	.992	25	75
		60	.977	.977	30	70

ng Tests

Water Evap. Cu. Cent.	Calories Used	Time to Use 1000 Cal.	Cu. Ft. or Kw. Hr. per 1000 Cal.	Cost per 1000 Cal. Cents
168	109	552	41.8	4.18
144	96	417	42.8	4.28
223	122	377	60.6	6.06
600	541	73.9	31.2	3.12
1174	809	148	36.5	3.65
1854	1209	74	31.6	3.16
90	137	219	1.76	1.76
548	393	229	1.96	1.96
792	898	184	1.56	1.56
124	83	605	1.88	1.88
177	117	515	2.33	2.33
177	116	260	1.72	1.72
184	172	387	9.09	9.09
80	114	397	9.20	9.20
530	361	111	5.52	5.52
525	353	123	5.56	5.56

These results show that, so far as power is comcerned, the university can more economically use electricity for heating laboratory apparatus than gas. However, there are other cansider ations. In the first place, most of the electric heaters are much slower than the corresponding type of gas heater. Next, there is but one type of electric heater on the market for heating test tubes, and this type is merely an adaption of a hot plate for heating a number of tubes at once. These two considerations are vital, for they affect about seventy-five per cent of the work done in the chemical laboratory.-- most of the work requiring rapid heating and very few operations necessitating the heating of a number of test tubes at the same time. Finally, the original cost of these electric heaters almost prohibits their installation in the great numbers needed to supply all of the students enrolled in the first two years of the laboratory work. The conclusion to be drawn from the above statements is that some new types of appliances of cheap construction are needed.

Construction of New Appliances. Therefore, the second part of this work was undertaken with the object of devising some simple test tube heater and a simple hot plate. Since test tubes are usually heated one at a time, the construction was planned along this line. The Ceramics Department was looked to as a source of insulating material.

The following list gives a brief description of the heaters constructed, and the method of constructing and testing.

(1) A six inch by three-quarter inch test tube was wrapped with a sheet of asbestos paper. Upon this was wound a piece of #24 Chromel wire eleven feet long. This was given a double wrapping of asbestos paper for insulation. Two carbon resistances were put in series with the heater and adjusted to give 60 volts across the terminals of the heater and a wattage of 200. Twenty-five

cubic centimeters of water were heated from 25°C. to boiling in 30 seconds.

(2) In the construction of this heater, the test tube was given a one-sixteenth inch coat of asphalt. Upon this was wound 3.2 feet of #35 Chromel wire and a cover of asbestos paper. Twenty-five cubic centimeters of water were raised from 24° Centigrade to boiling in 45 seconds with a power of 150 watts.

(3) This was a duplicate of (2), except that 4.0 feet of #35 wire were used. With 120 watts, 25 cubic centimeters of water were raised from 30°C. to boiling in one minute.

(4) This was made as (3), but about a one inch by six inches test tube. The wire layer was coated with a cement made of 70% ordinary fire clay and 30% Valentine clay , both ground to sixty mesh, and water glass. In the test 50 cubic centimeters of water were heated from 30° to boiling in three minutes; average power used was 120 watts. The cost of a heater like this is 1.3 cents for materials and practically nothing for the workmanship.

(5) A concave plate, four inches in diameter and one-half inch thick, was made of the above cement in which the clay had only been ground to 40 mesh. The concave surface was coated with asphalt and wound with nine feet of #24 Chromel wire. This was then protected with a thin coat of cement. Two test runs were made with a voltage of 102 across the terminals of the plate, there being a drop of 8 volts in the cord from the plug, and 850 watts.

(6) This plate was similar to (5) with the exception that the wire was 3.5 feet of #28. With 270 watts at 60 volts, the temperature of the surface of the plate was raised from 30°C. to over 370°C. in nine minutes; this used .045 kilowatt hours and cost .045 cents. Then 250 cubic centimeters of water were heated in a 500 cubic centimeter flask for 75 minutes.

(7) This was exactly similar to the other two plates except that

the thirteen feet of #22 wire used was wound about asbestos rope, and that this rope was then coiled upon the bottom plate and held there with water glass. Test run was similar to the others with a voltage of 55 and 260 watts power.

The results of the tests upon the devices described are given in the table below.

Device Number	Temp. of Water Deg. Cent.		Water Evap. cc.	Calories Used	Time to Use M Cal. Min.	Kw. Hr. per M Cal.	Cost per M Cal.
	Initial	Rise					
1	25	75	--	1.88	444	1.47	1.47
2	24	76	--	1.90	395	0.99	0.99
3	30	70	--	1.75	571	1.14	1.14
4	30	70	--	3.50	857	1.03	1.03
5	26.5	28.5	--	7.13	210	2.98	2.98
	25	30	--	7.50	267	3.78	3.78
6	27	73	210	138	554	2.45	2.45
7	20	80	82	63.9	936	4.06	4.06

The results of these tests upon the heaters indicate that the electric heating devices can be constructed for much less than they now sell for. They also indicate that the hot plate could be improved by making the concave surface six inches in diameter and winding it with a longer piece of heavier wire, if possible without the use of asbestos cord or similar material; this should make it heat more rapidly and less apt to break down due to fusion of the wire. The Materials for the construction of the test tube heater cost 1.3 cents; hence, they should not cost more than 25 cents each with a cord and plug, if made in large numbers. The materials for the hot plates range in cost from 10 to 20 cents; thus, a conservative estimate for the plate, cord, and plug is 50 cents. This cost figure should almost cover the labor cost, for with winding machines, etc., they could be produced very rapidly. The Simplex Hot Plate #1702, 6 inch,

440 watts(one speed), with six feet of cord and a plug, costs $6.00. Thus the new heater costs approximately ten per cent of the selling price of the present hot plate of the same capacity.

SUMMARY

1.- The greater efficiency of the electric heating devices makes them more economical than similar gas devices where electricity costs but one cent per kilowatt hour and gas costs one dollar per 1000 cubic feet.

2.- The electric heating devices now upon the market are too expensive to be supplied to all students in place of the gas appliances now in use. But, electric devices having the same efficiency of those now upon the market may be made of cheaper materials. Those of cheaper materials could be made to retail at one-fifth to one-tenth of the price of the present devices.

3.- The individual electric test tube heater is much more economical than the Bunsen burner which is at present used, both in test runs and in that it would be used in a more economical manner in actual practice.

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